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IN-FLIGHT AERODYNAMIC NOISE MEASUREMENTS ON A SCOUT LAUNCH VEHICLE

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SUMMARY

The results of free-flight surface-pressure measurements are presented for a Scout launch vehicle for Mach numbers up to about 4, free-stream dynamic pressures up to about 2,300 lb/sq ft, and Reynolds numbers based on vehicle length up to about 400 million. Useful data from two onboard microphones up to the time of second-stage ignition were telemetered to the ground station for recording and analysis. The overall surface noise levels were noted to increase roughly as the dynamic pressure increased, but did not vary markedly as a function of Mach number. However, a Mach number effect on the spectral content of the surface noise pressures was noted as a general result of the tests. In particular, the spectra at the higher Mach numbers contained relatively more high-frequency noise and relatively less low-frequency noise than spectra measured at low speeds. The results of the tests are compared with available data from other free-flight studies.

INTRODUCTION

For advanced aircraft, missiles, and spacecraft, aerodynamic noise may be significant from the standpoint of exciting directly modes of the structure, causing sensitive equipment to malfunction, or interfering with the normal duty functions of the vehicle occupants. The physical characteristics of the aerodynamic noise (fluctuating surface pressures) may be a function of the vehicle configuration, including its surface conditions, the operating conditions or trajectory of the vehicle, and to some extent the atmosphere itself. There is the suggestion, then, that some of these fluctuating pressure disturbances may be altered by the configuration design. However, other fluctuating pressure disturbances can not be altered by vehicle configuration and thus must be allowed for in the structural design.

Although numerous studies relative to the aerodynamic noise problem are available (see ref. 1), only a few free-flight surface-pressure-measurement experiments have been conducted (see, for example, refs. 2 to 8). Free-flight data in the Mach number and Reynolds number ranges of significance for supersonic transports and launch vehicles are particularly scarce. The main objective of the present paper is to present some free-flight surface-pressure measurements for a Scout launch vehicle for Mach numbers up to about 4 and for a range of Reynolds numbers up to about 400 million. Some discussion is also directed toward the equipment and techniques used to obtain these data.

SYMBOLS

h	altitude, ft
M	free-stream Mach number
q	free-stream dynamic pressure, lb/sq ft
$\sqrt{\overline{p^2}}$	root-mean-square surface pressure, lb/sq ft

APPARATUS AND METHODS

Vehicle Description and Performance

An instrumentation package for measuring surface pressures was included as an experiment on a Scout launch vehicle. The primary mission of this vehicle was to provide the required boost for a radiative-heat-transfer reentry project. (See ref. 9.)

The Scout was a five-stage, solid-propellant launch vehicle (see fig. 1) with the fifth stage being an integral part of the primary payload assembly. The vehicle was launched from the NASA Wallops Station on August 31, 1962, at 12:25 a.m. eastern daylight time with a launch azimuth of 130.5° true and a vehicle launch angle of 84.5°.

General arrangement of the Scout launch vehicle, including major body dimensions and microphone mounting locations, is shown in figure 2. The vehicle was approximately 72 feet in length with a maximum diameter of 40 inches. The two microphone measuring stations were located 34 feet (upper "B" transition) and 68 feet (base section "A"), respectively, from the nose of the vehicle. Hereinafter, these measuring stations and the associated microphones will be referred to as microphones 1 and 2, respectively.

Trajectory data for the Scout vehicle from approximately 8 seconds after lift-off to second-stage ignition are shown in figure 3. These data were calculated by using information acquired by the use of radar tracking facilities located at the launch site. It can be seen that the vehicle attained Mach numbers in excess of 4, a maximum free-stream dynamic pressure of approximately 2,300 lb/sq ft, and an altitude of 160,000 feet during the period for which noise data were measured.

Instrumentation

The instrumentation system used for obtaining the surface-pressure measurements was developed by Chance Vought Corp., and consisted primarily of two microphone data channels and a telemeter transmitter. The noise data from the two microphone data channels were telemetered via one telemeter data link. The main onboard components of the noise-measuring instrumentation are shown in figure 4. The total weight of the entire package including microphones, microphone amplifiers, subcarrier oscillator, wide-band amplifier, telemeter transmitter, battery pack, and associated wiring was approximately 12.6 pounds.

The microphones used were of the piezoelectric (lead zirconate) type with a 1/4-mil stainless-steel diaphragm having a 1/2-inch diameter. They were mounted with the diaphragms flush with the external surface of the vehicle. This method of mounting resulted in an orientation such that the microphone diaphragms were generally parallel to the thrust axis of the vehicle. A vibration-sensitive seismic system (contained within the microphone case) is connected in opposition to the microphone system and, thus, effectively compensates for vibration along the sensitive axis of the microphone. (With the application of a vibration force of 1 g root mean square, the electrical output of the microphone did not exceed that obtained at a sound pressure level of 90 decibels.)

In order to compensate for altitude changes during the experiment, the internal volume of each microphone was evacuated to 10^{-4} millimeters of mercury and then sealed. The microphones were designed to operate with no appreciable effect due to temperature on their frequency response or sensitivity in a temperature range from 0° F to 450° F. The frequency responses of the microphones remained constant to within ±2 decibels from 15 cps to 10,000 cps. The overall system response, however, was limited at the lower frequencies by other components.

The signal from microphone 1 frequency-modulated the telemeter-transmitter frequency directly. The microphone-amplifier gain was adjusted so that the maximum expected sound pressure level of 145 decibels would deviate the telemeter-transmitter frequency ±75 kilocycles. The upper frequency response of microphone channel 1 was limited to 10,000 cps by a filter in order to eliminate interference to microphone channel 2. The combination of the transmitter and the ground-receiver responses imposed a lower frequency limit of approximately 100 cps on the data obtained from microphone channel 1. The signal from microphone 2 frequency-modulated the 70-kilocycle subcarrier oscillator. The microphone-amplifier gain was adjusted so that the maximum expected sound pressure level of 155 decibels would deviate the frequency of the 70-kilocycle oscillator ±10.5 kilocycles. The deviated output signal of the 70-kilocycle oscillator was combined with the signal of microphone 1 in order to frequency-modulate the telemeter transmitter. The gain of the wide-band amplifier was adjusted so that the amplitude of the output signal of the 70-kilocycle oscillator would deviate the telemeter-transmitter frequency ±50 kilocycles. The response of microphone channel 1 remained constant to within ±2 decibels from 20 cps to approximately 7,500 cps and dropped off approximately 4 decibels at 10,000 cps. The overall dynamic range of each of the data channels was approximately 40 decibels.

Just prior to the actual launching of the Scout vehicle, the entire data acquisition system was calibrated, first with the use of a high-level acoustic calibrator and then by inserting known voltage levels into different points of each channel, thus, an accurate indication of the sensitivity and frequency response of the entire system including onboard and ground instrumentation was obtained.

Data Reduction

After the flight, the recorded data tapes were played back and demodulated. Microphone 1 data were separated out directly by using a 10-kilocycle low-pass filter. Microphone 2 data were first passed through a band-pass filter (70-kilocycle ±10.5-kilocycle) and were then separated out by using a discriminator having a center frequency of 70 kilocycles. The acoustic data were then analyzed with the use of an octave-band analyzer and a graphic level recorder.

Atmospheric Conditions

Surface conditions just prior to the launch of the Scout vehicle were as follows:

Pressure, mb	1,016
Temperature, $^{\circ}F$	74
Wind, deg/7 knots	191

The variations of ambient conditions in the atmosphere up to an altitude of 90,000 feet, obtained by means of a rawinsonde, are presented as a function of altitude in figures 5 and 6. The speed of sound and the density are not markedly different from those of the U.S. standard atmosphere (ref. 10), and the wind velocities did not exceed 25 knots.

RESULTS AND DISCUSSION

The manner in which the sound pressure level varied as a function of time for each of the measuring stations of the Scout launch vehicle is indicated in figure 7. It can be seen that in the case of microphone 2, valid data were obtained from shortly after launch through first-stage operation and the coast period between first-stage burnout and second-stage ignition. In the case of microphone 1, similar results were obtained except that some data were lost during the flight because the dynamic range of the data channel was exceeded for a portion of the flight. It is believed that valid data recordings were obtained both before and after this difficulty occurred.

As in some previous experiments, it was noted that the noise pressures increased as the free-stream dynamic pressure increased. This phenomenon is illustrated by the curves of figure 8 in which the vehicle free-stream dynamic pressure and the measured noise pressures from microphone 2 are plotted as a function of time. It can be seen that during the first part of the flight the noise-pressure curve follows the dynamic-pressure curve quite closely. It can, however, be seen that the noise-pressure curve peaks at an earlier time than the dynamic-pressure curve, and furthermore there is a subsequent deviation from the trend of the dynamic-pressure curve. This deviation may be explained in part by a Mach number effect, which is described in more detail in figures 9 and 10.

The tape records from which the data of figures 7 and 8 were obtained were also played back through an octave-band filter system in order to obtain time histories of the sound pressure levels in each octave band. These data have been cross-plotted for several times of interest during the flight in order to obtain the spectra at those flight conditions. These noise spectra are plotted in figure 9 for several different Mach numbers and the associated free-stream dynamic pressures. It can be seen that at low Mach numbers, there is a broad peak in the spectra in the vicinity of the frequency bands of 600 to 1,200 cps and 1,200 to 2,400 cps. This peak gradually shifts to higher frequencies as the Mach number increases. Specifically, there is a lesser contribution of the lower frequency components and a greater contribution of the higher frequency components at the higher Mach numbers. At the higher Mach numbers there is, however, a suggestion that the peak in the spectrum may occur at frequencies above those for which the measurement equipment was designed, and hence the contributions of these higher frequencies are probably underestimated. As in figure 7, the data for microphone 1 have been omitted at the times for which saturation of the data channel may have occurred.

As was noted in the discussion of figure 8, the noise-pressure time history followed roughly the free-stream dynamic-pressure time history. Because of this apparent direct relationship between the noise pressures and the free-stream dynamic pressures, the data are presented in the form of pressure coefficients $\sqrt{\overline{p^2}}/q$ in figure 10. These pressure coefficients, which are plotted as a function of Mach number for both measuring stations, range from 0.005 to 0.010. The data indicate a trend toward reduced values of pressure coefficients as the Mach number increases for the range of Mach numbers from about 1.0 to 4.0. It is believed, however, that the reduced pressure-coefficient values at the higher Mach numbers are due in part to the fact that the higher frequency components are underestimated in the measurements. The dashed portions of the curves at high Mach numbers correspond to flight conditions at high altitude and very low associated dynamic pressures. The signal-to-noise ratios are rather low at these latter conditions, and thus the dashed curves are based on less reliable data.

COMPARISON WITH OTHER DATA

The range of pressure-coefficient values measured for the Scout launch vehicle is compared with similar data from other free-flight studies in figure 11. It can be seen that the data for the Scout compare favorably in magnitude with those measured for two bomber airplanes (refs. 5 and 6) for which the Reynolds numbers were of comparable magnitude. These pressure-coefficient values for the Scout are considerably higher than those measured on the nose cone of a fighter airplane (ref. 7) for which the Reynolds numbers were much lower, and hence the local-flow conditions might have been considerably different. The Scout data are notably lower, however, than those measured for the Mercury spacecraft (ref. 8), which had rough external contouring and possible associated flow separation and shock-wave interactions. The Scout data are also markedly lower than localized pressure coefficients measured during buffeting studies of space-vehicle models in wind tunnels. (See ref. 11.)

CONCLUDING REMARKS

A brief discussion has been given of an experiment in which aerodynamic noise data were obtained with the aid of a Scout launch vehicle from which real-time information was telemetered to a ground recording station. The results of this experiment indicate a shift in spectrum shape as a function of Mach number; that is, the higher frequencies are associated with the higher Mach numbers. Another result suggests that the surface-pressure coefficients at supersonic Mach numbers do not vary markedly from those at subsonic Mach numbers for comparable flow conditions.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., April 4, 1963.

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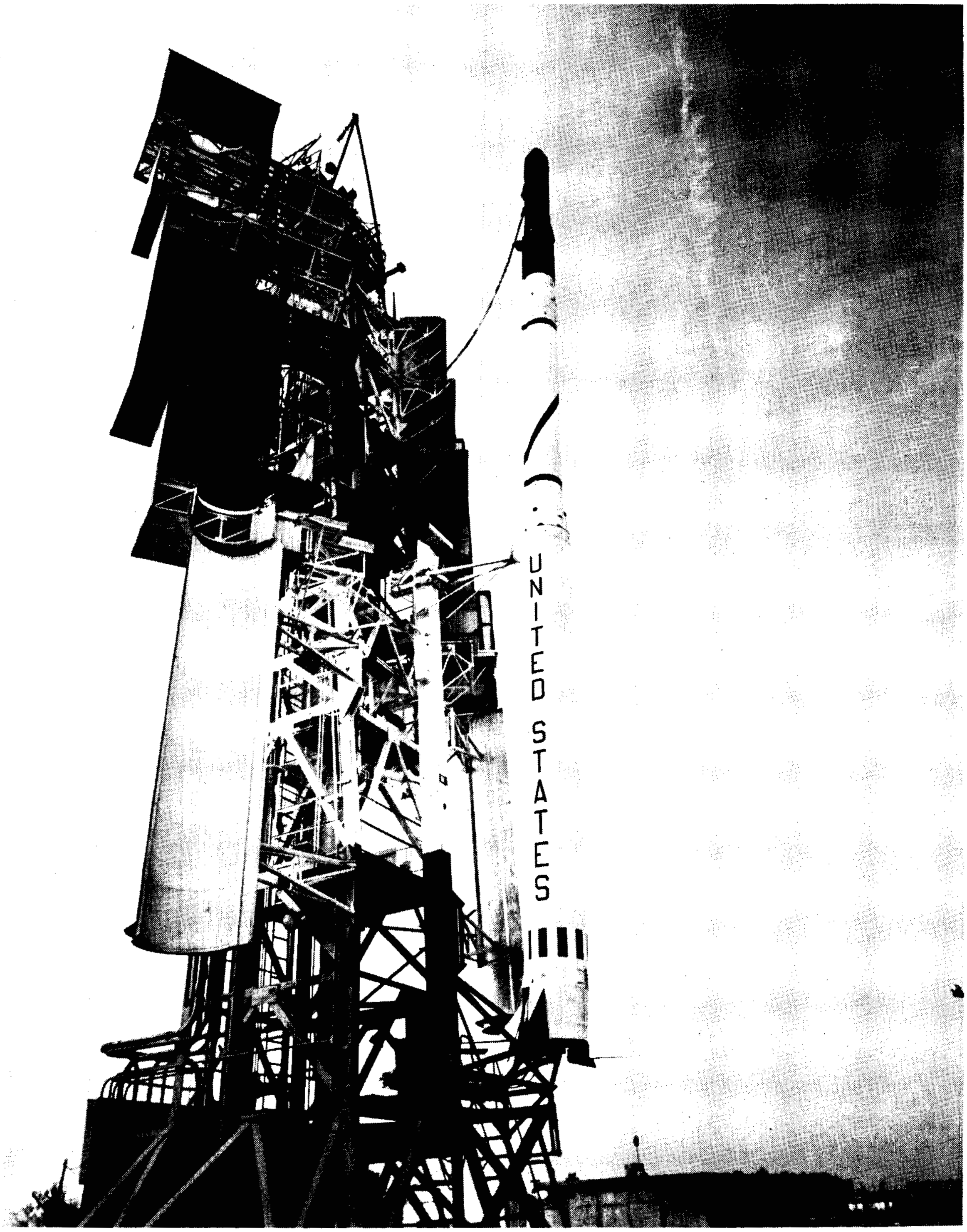

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Figure 1.- Scout launch vehicle on tower.

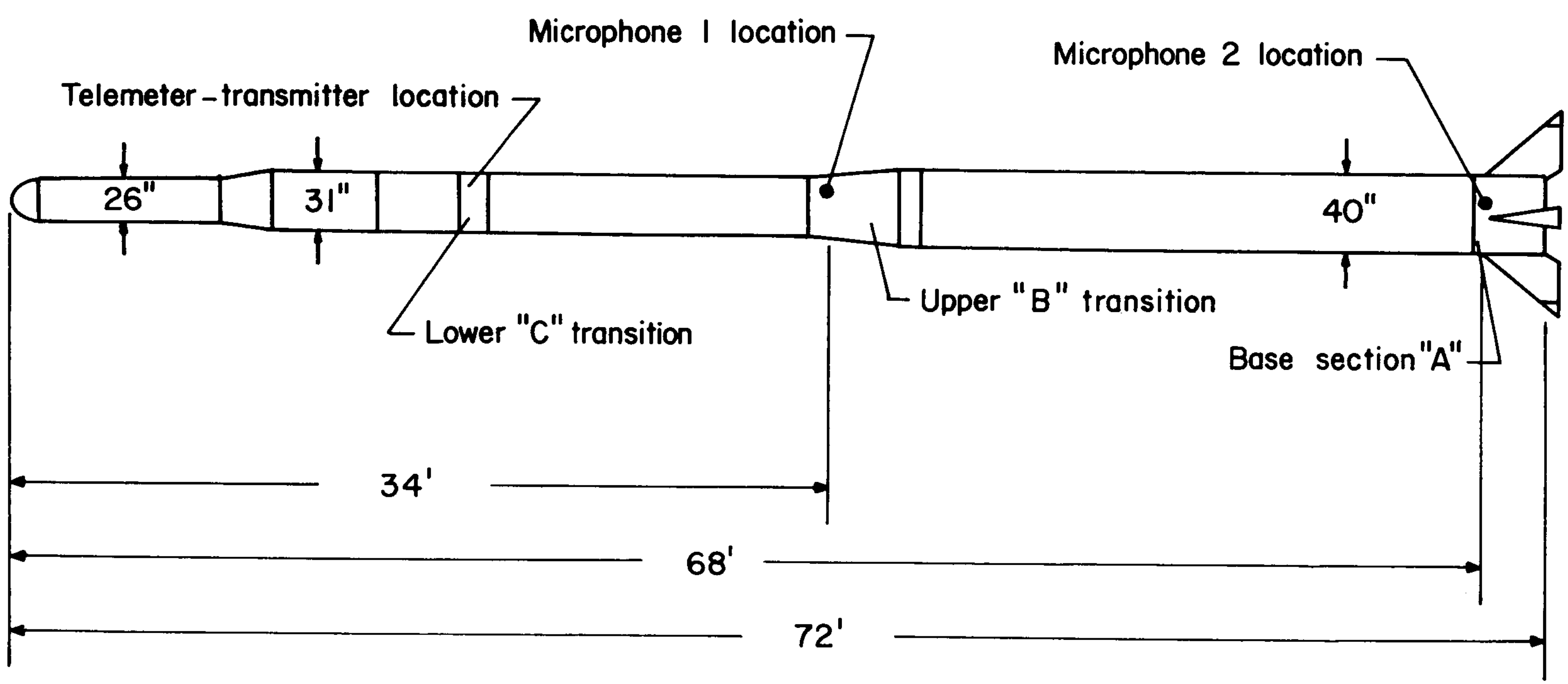

Figure 2.- Sketch of Scout launch vehicle showing major dimensions and microphone locations.

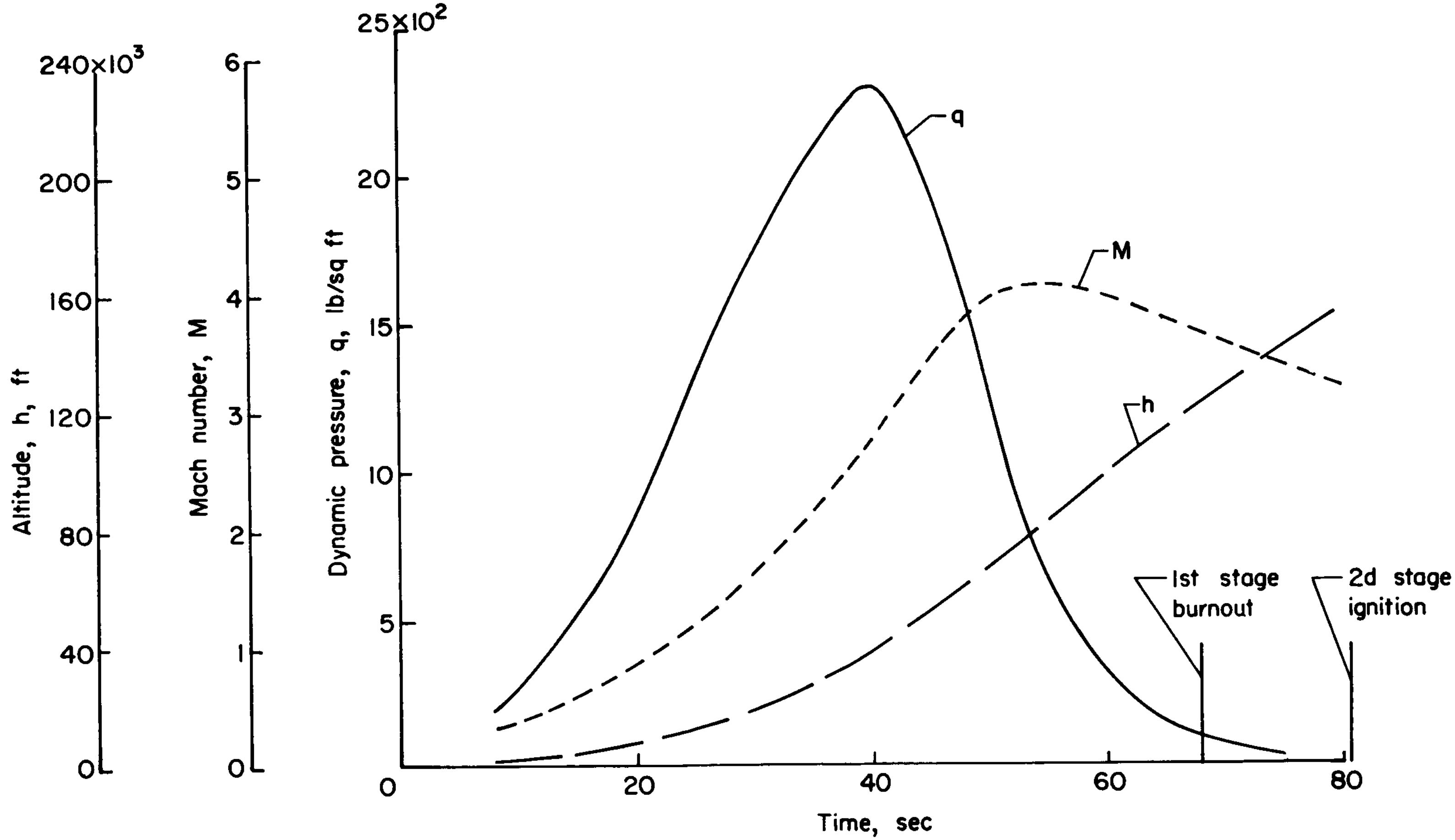

Figure 3.- Time history of Mach number, dynamic pressure, and altitude for Scout launch vehicle.

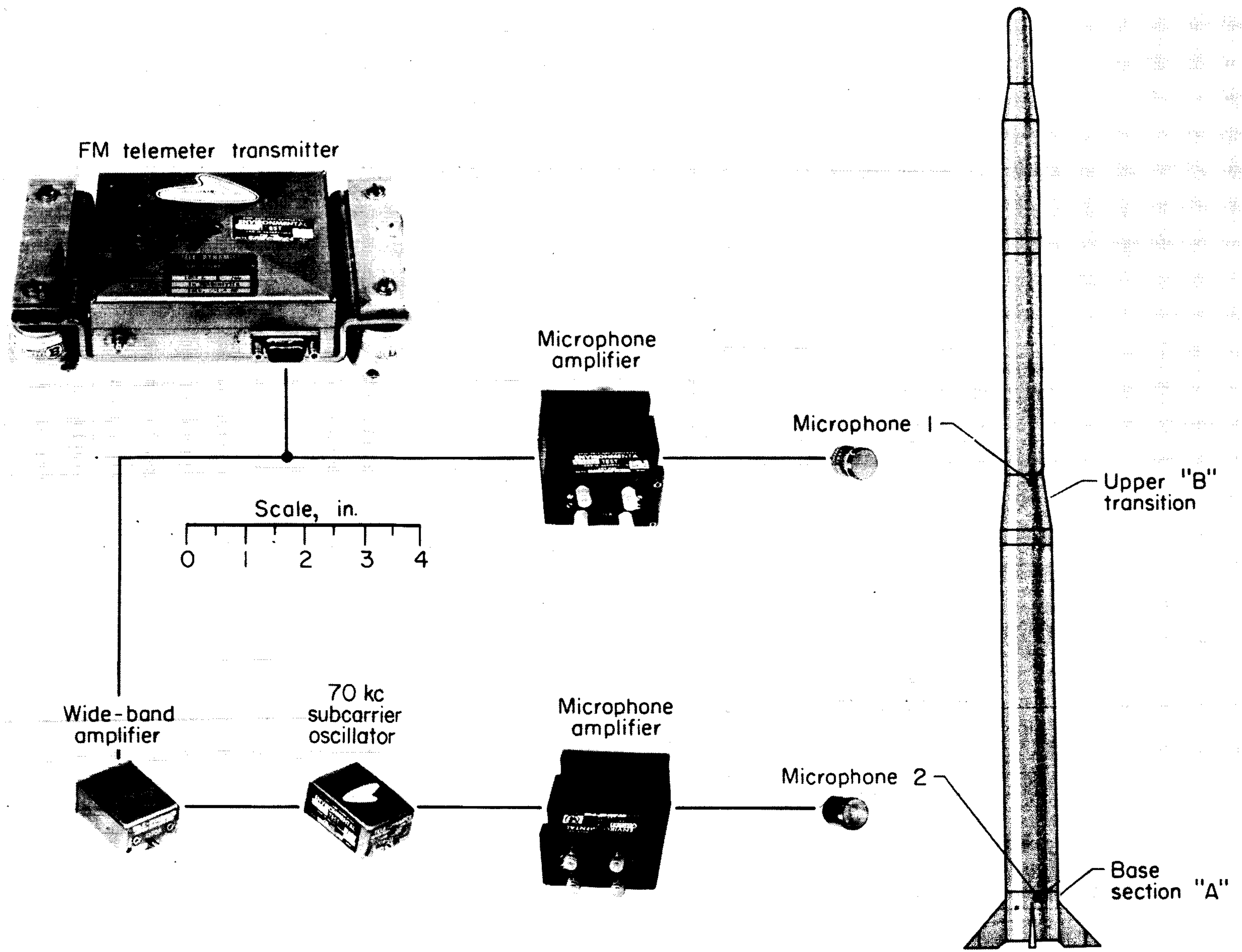

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Figure 4.- Onboard acoustic instrumentation for Scout launch vehicle.

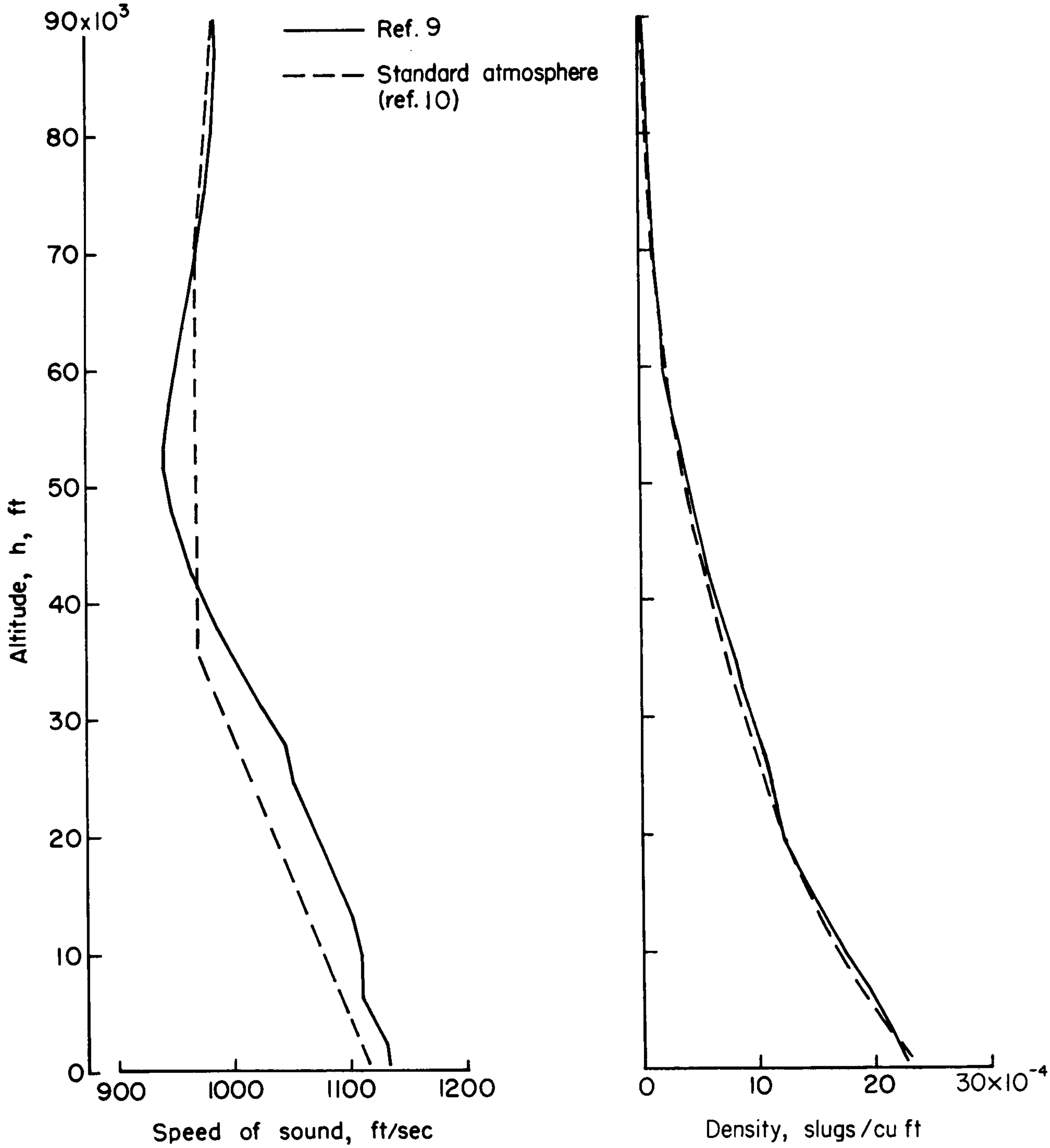

Figure 5.- Speed of sound and ambient air density as functions of altitude.

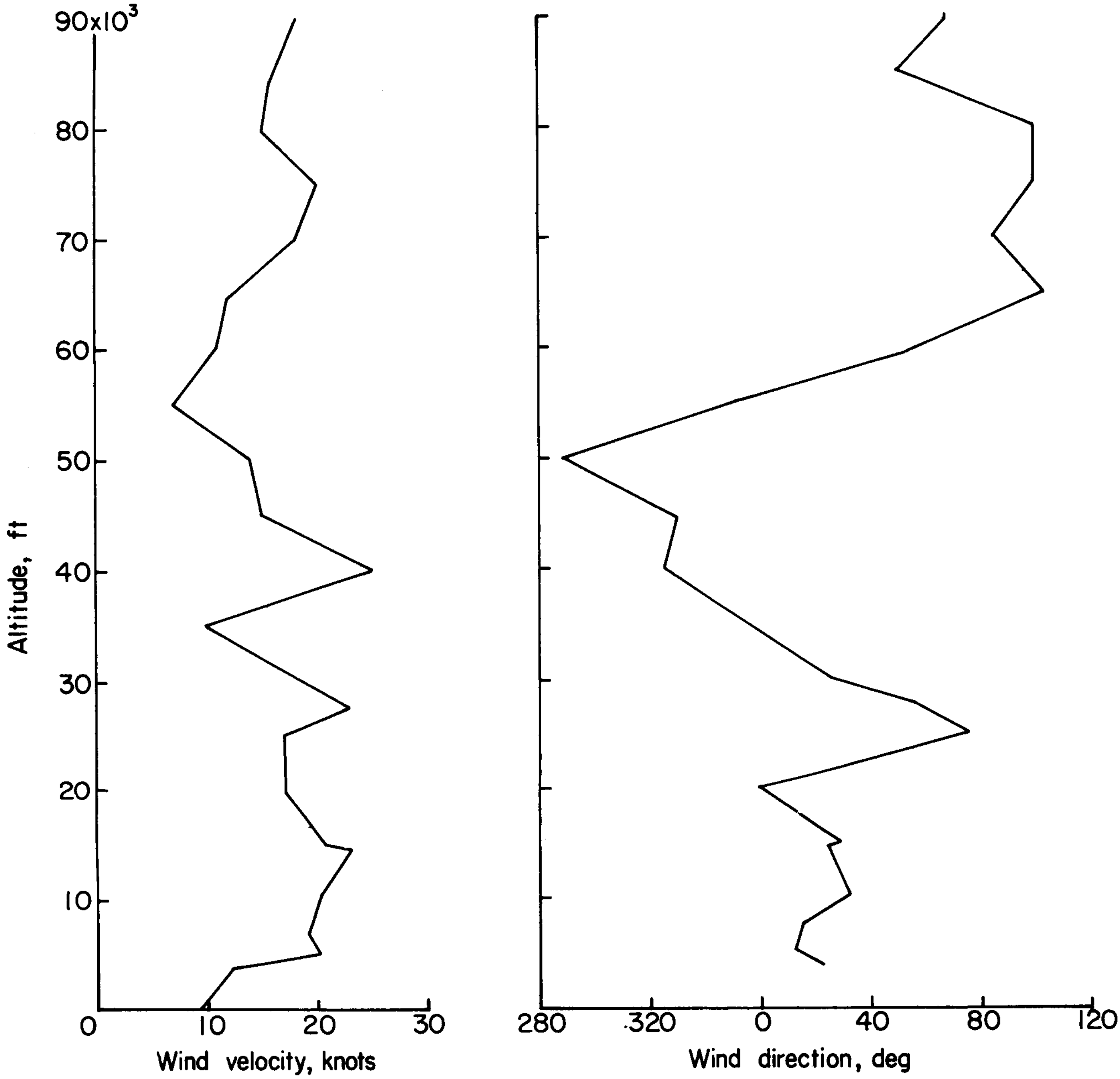

Figure 6.- Wind velocity and direction as functions of altitude (from ref. 9).

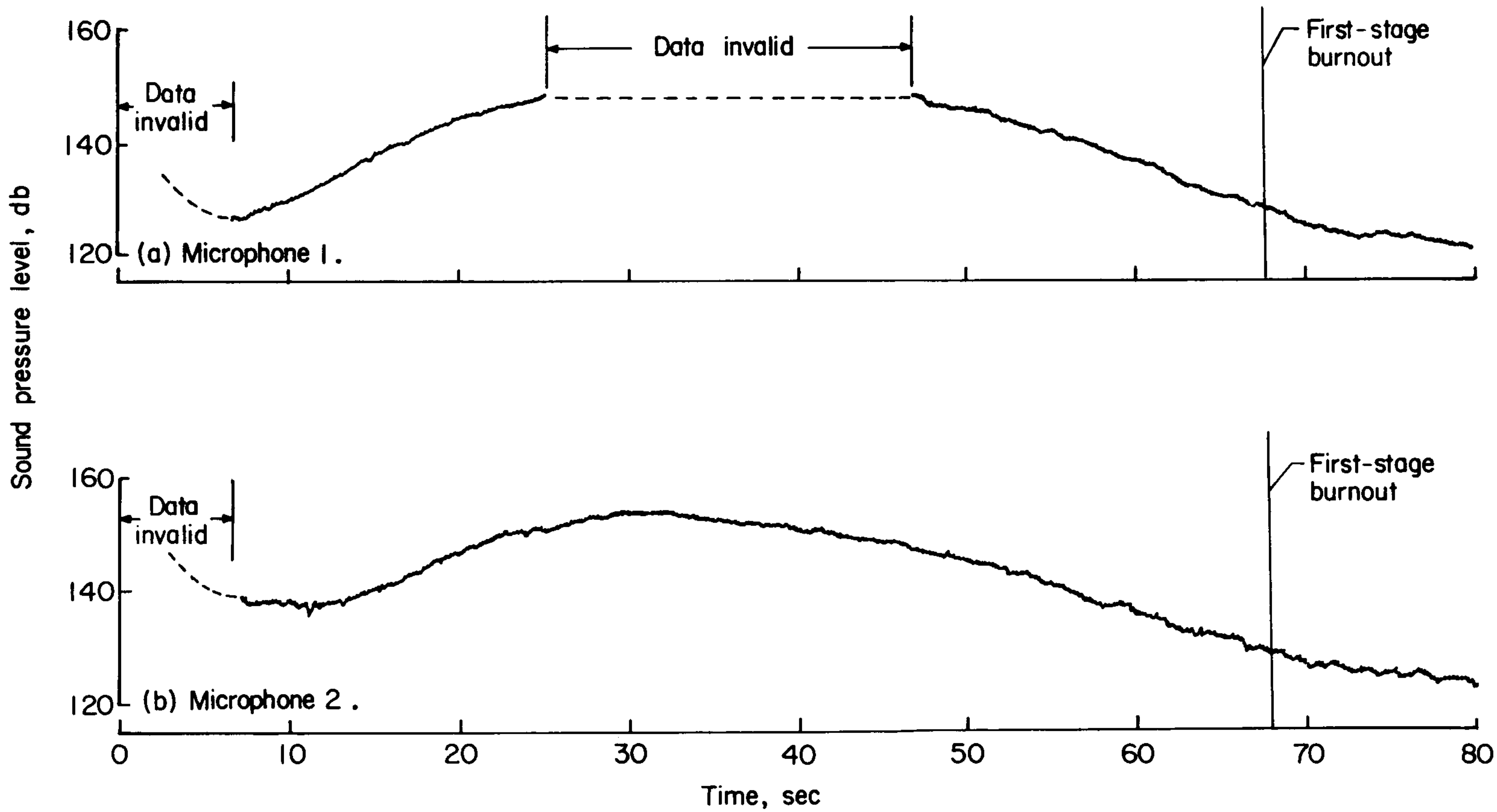

Figure 7.- Overall sound-pressure-level time histories at two locations on surface of Scout launch vehicle.

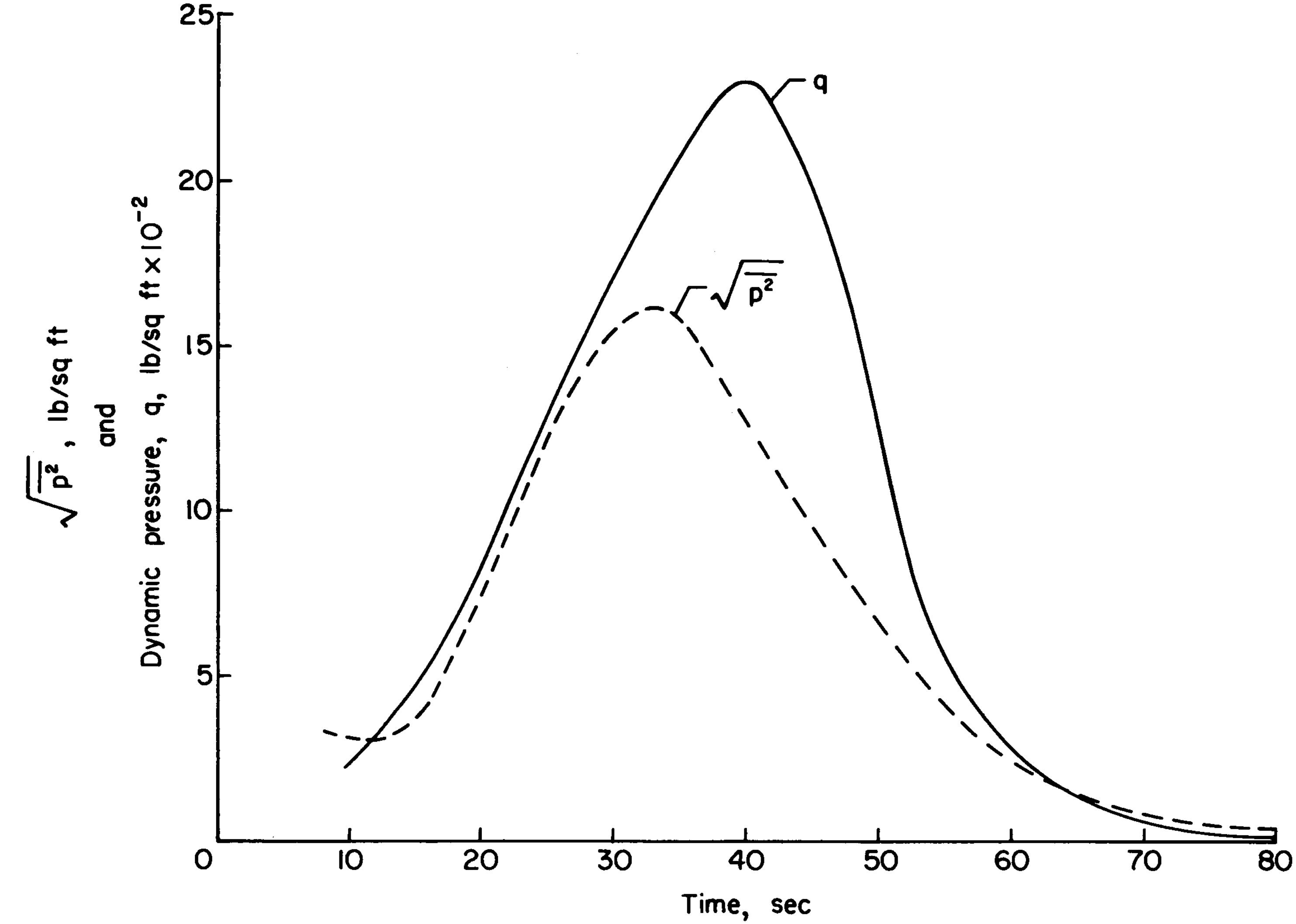

Figure 8.- Comparison of root-mean-square sound pressure for microphone 2 with free-stream dynamic pressure as a function of time for Scout launch vehicle.

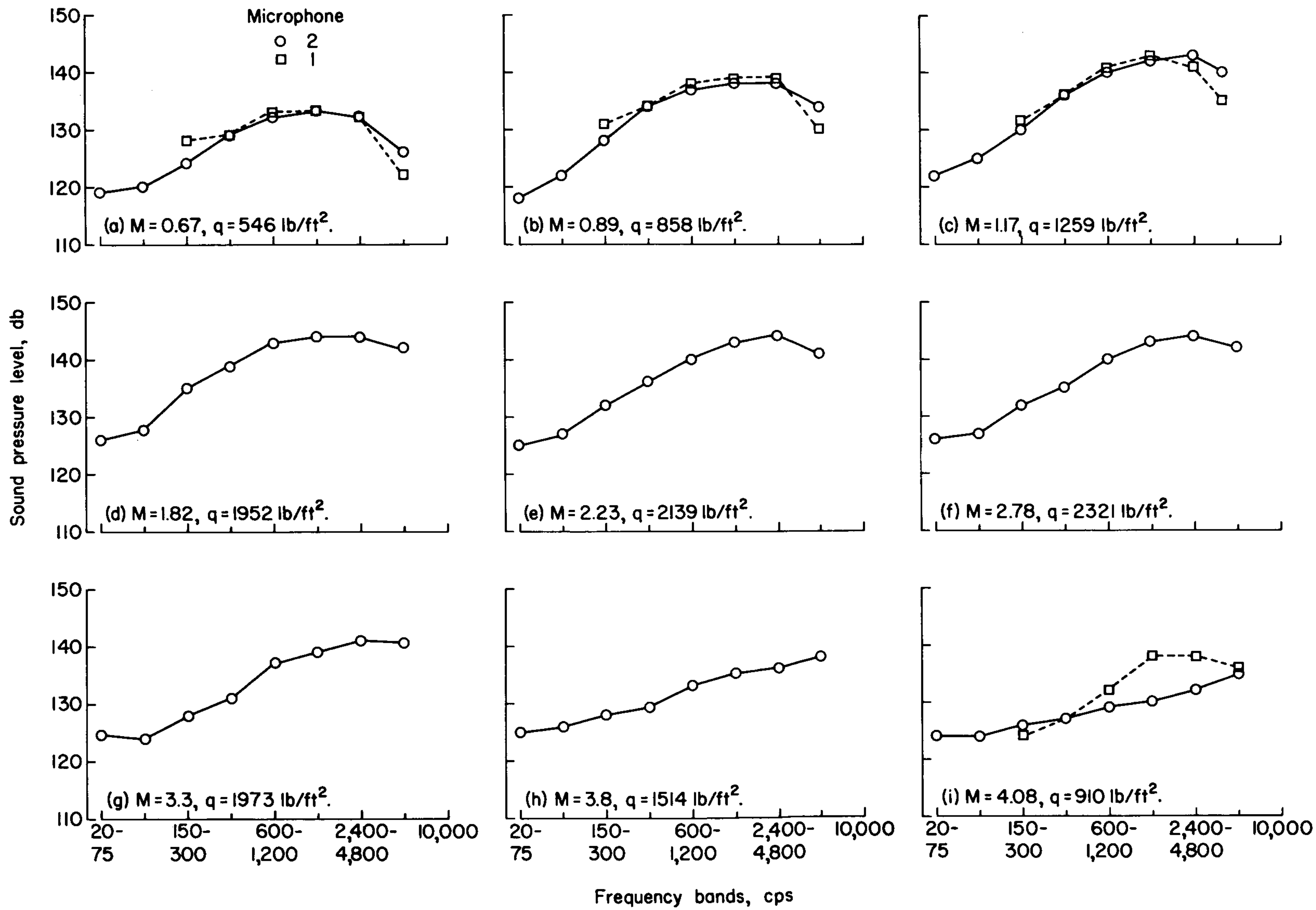

Figure 9.- Octave-band spectra for both data channels at various Mach numbers and associated dynamic pressures.

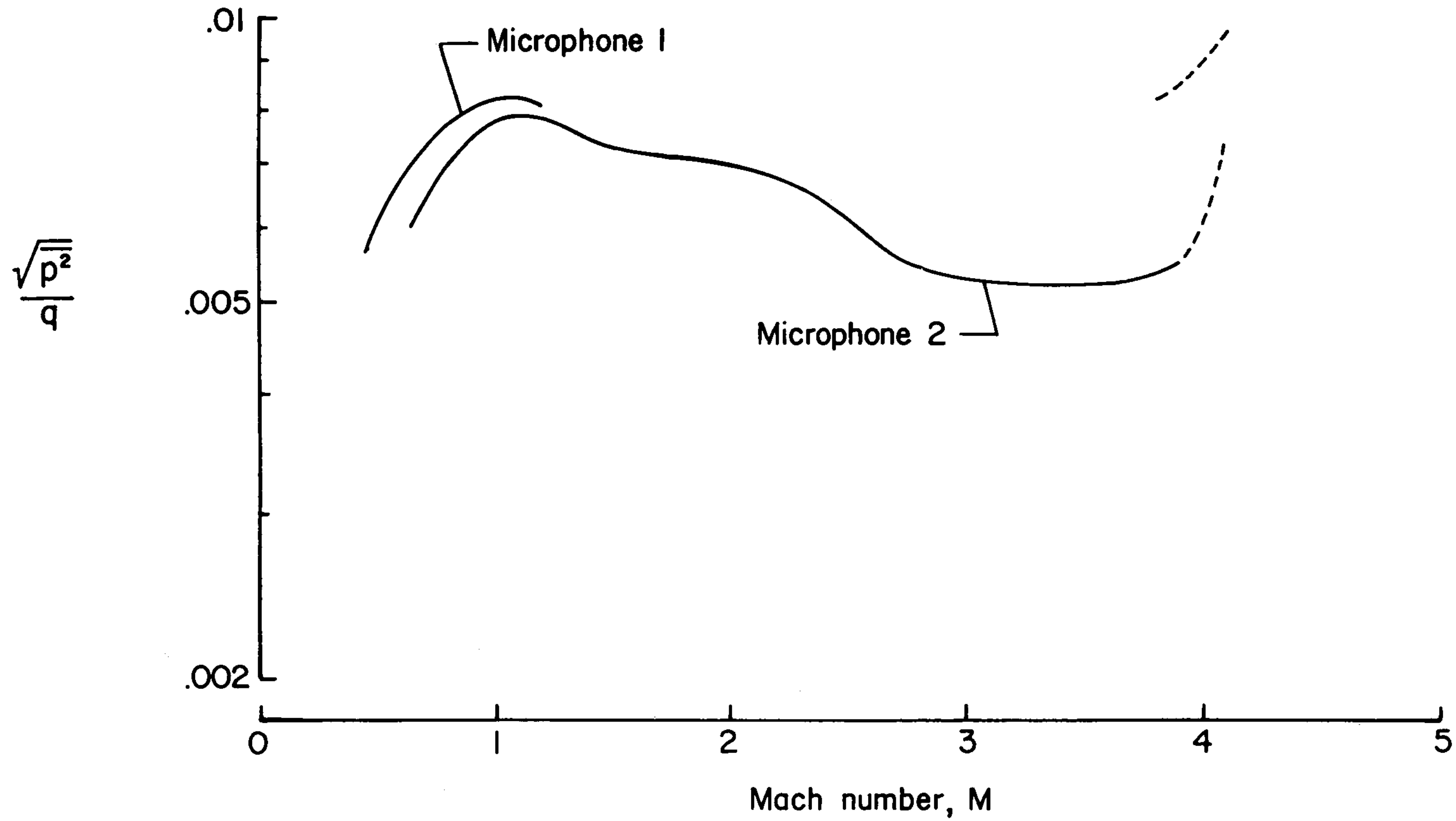

Figure 10.- Surface-pressure coefficients as a function of Mach number for Scout launch vehicle (dashed lines indicate questionable data).

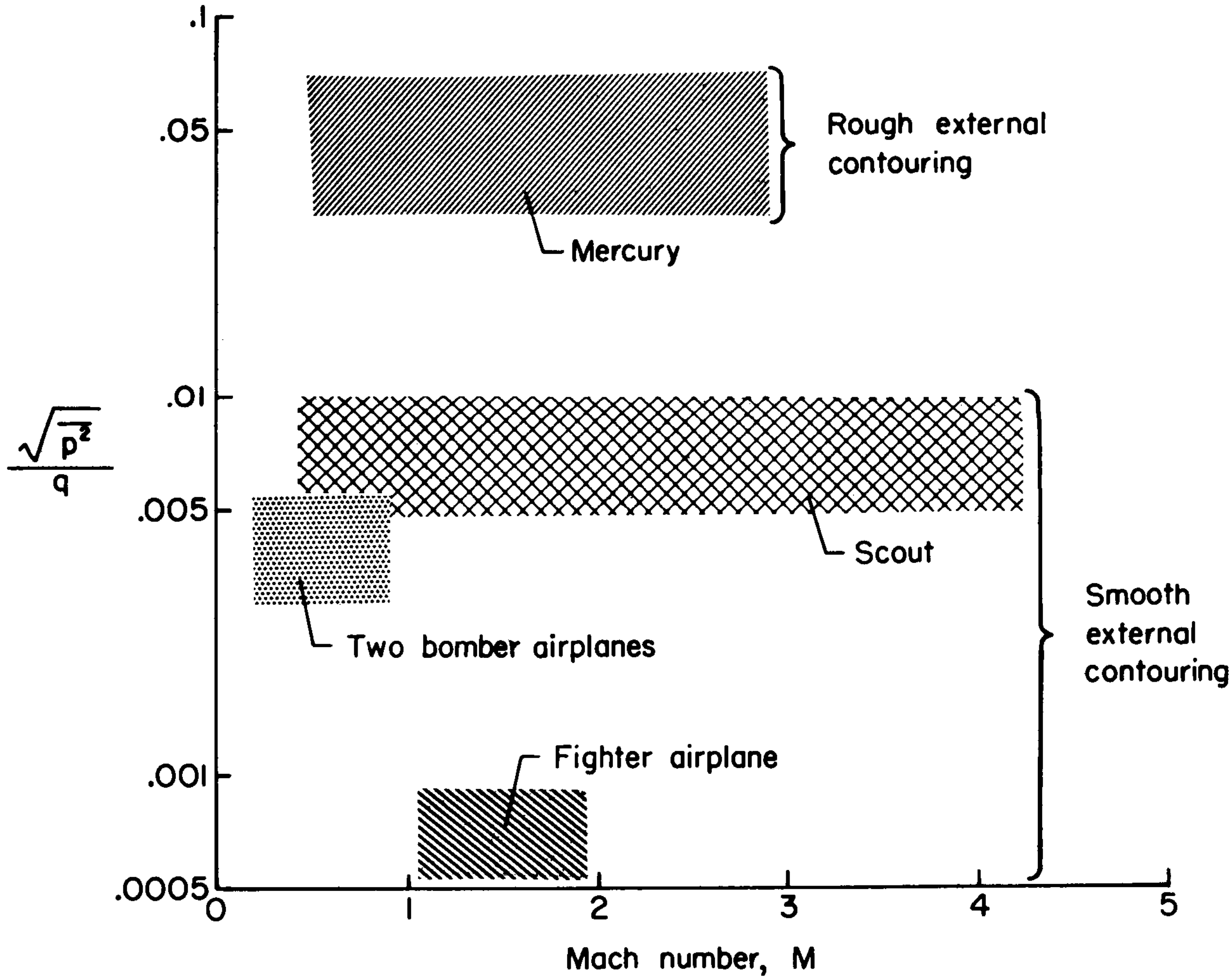

Figure 11.- Comparison of surface-pressure coefficients for Scout launch vehicle with other available data.

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